



Rapid Repair Materials and Construction

Rapid Bridge Repair Workshop
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What is a successful rapid bridge repair ?

- A durable repair that is done safely and with a minimum of congestion.
- The repair is done with reduced user costs compared to a standard repair because traffic delays caused by lane closures are reduced.



What is required for a successful rapid repair ?

- Use of rapid hardening/curing materials and prefabricated bridge elements are typically associated with a rapid repair.
- However, to be successful the entire project must be designed for durability, safety and minimal congestion.
- This includes work required for mobilization, approach lanes, pavement marking, safety barriers, repairs and incidentals.
- Often times rapid materials are specified but the contract fails to consider other aspects of the project and a rapid repair is not achieved.
- Sometimes conventional materials can be used.



Typical bridge repairs

- Sealing concrete and filling cracks
- Joint repairs
- Patching
- Overlays
- Deck replacement
- Beam repair
- Beam replacement
- Substructure repairs
- Substructure replacement

Is a rapid repair needed?

- Preliminary planning must be done to identify lane closure and repair options.
- Depending on the lane closure and repair options a rapid repair may or may not be needed.

Lane closure options

- **Short duration lane closures:** night, day, weekends (use **rapid repair** materials and construction).
- **Permanent lane closure** (traffic not an issue, **conventional repairs** may be suitable).
- **Temporary detour** to maintain traffic capacity (traffic not an issue, **conventional repairs** may be suitable).
- **Provide additional lanes** by widening bridge so that traffic can be diverted to the new lanes during overlay placement. New lanes are available for future repairs/maintenance and to allow for future increases in traffic capacity (traffic not an issue, **conventional repairs** may be suitable).

Continuous lane closure for overlay

- Conventional repairs may be acceptable.
- Rapid repair may **not** be **needed** except for final spans.



Rapid Repair Materials and Construction

- Rapid hardening/curing materials
- Prefabricated bridge elements



Rapid hardening/curing materials

- Sealing concrete
- Filling cracks in concrete
- Joint repair
- Patching
- Overlays
- Connections for prefabricated elements used for deck replacement



Prefabricated bridge elements

- Superstructure slabs
- Deck slabs
- Beam and deck slabs
- Parapets
- Precast substructure elements

- Prefabricated bridge

Rapid hardening/curing materials

- Sealing concrete
- Filling cracks in concrete
- Joint repair
- Patching
- Overlays
- Connections for prefabricated decks

Sealing Concrete

- Water repellents such as silanes and siloxanes typically **cure faster**
- Pore blockers such as acrylics, linseed oil, epoxy, polyester, gum resin and urethane typically **cure slower**
- Cure time affected by the condition of the concrete, temperature and relative humidity



Sealing Concrete

- Apply sealer with broom, squeegee or low pressure spray
- Refer to List 30 Sealants, Stains and Coatings, VDOT website: materials/approved_lists)
- Additional information:
Maine DOT approved products list, concrete sealers
NCHRP Synthesis 209 Sealers for Portland Cement Concrete Highway Facilities

Rapid hardening/curing materials

- Sealing concrete
- Filling cracks in concrete
- Joint repair
- Patching
- Overlays
- Connections for prefabricated decks

Filling cracks in concrete

- Materials include high molecular weight methacrylate, epoxy and urethane.
- Need to use materials with **rapid cure** but adequate pot life to penetrate cracks.
- Cure time affected by the condition of the concrete, temperature and relative humidity



Filling cracks in concrete

- Apply material over deck surface with broom, squeegee or low pressure spray
- Apply sufficient material to fill cracks
- Broom excess material from valleys of texture before it gels
- Treat individual cracks with small batches
- Refer to VDOT Special Provision for Gravity Filled Polymer Crack Sealing and List 28 Polymers for Sealing Cracks, VDOT website: [materials/approved_lists](#))

- Sealing concrete
- Filling cracks in concrete
- Joint repair
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Failed joint allows water and chlorides to reach substructure and cause corrosion deterioration



Joint repair

Two component silicone mixed in the nozzle is used to caulk a joint rapidly



Joint repair

Silicone is placed over backer rod to caulk a joint.
(Section 212 VDOT Road and Bridge Specifications)



Joint repair

Concrete is saw cut on both sides of joint to provide for removal of the old joint and concrete header



Joint repair

Joint assembly is placed into the prepared cavity. Very early strength patching material can be used to fill the cavity. Refer to List 31, HCC Patching Materials, VDOT website: materials/approved_lists.



Joint repair

Styrofoam is used to form the joint opening and List 31 polymer concrete is placed to construct the headers



Joint repair

Adhesive is applied to headers and joint is pressurized to hold it in place



- Sealing concrete
- Filling cracks in concrete
- Joint repair
- Patching
- Overlays
- Connections for prefabricated decks

- Refer to List 31, HCC Patching Materials, VDOT website: [materials/app._lists](https://www.vdot.com/materials/app_lists) for products that achieve 2500 psi comp. strength in ≤ 2 hours.
- Patch geometry and temperature affect strength development rate
- Concrete removal takes majority of time
- Patch geometry affects removal time
- Manpower and equipment affect patching rate



Patching

Sawcut perimeter 1 inch deep

Remove concrete using hammers weighing < 30 lbs



Patching

Place concrete into properly prepared cavity: saw cut perimeter, saturated surface dry surface, clearance under rebar, no rust on rebar

Consolidating concrete





Patching with ready mixed concrete

Recommended when feasible.



Patching with prepackaged materials

Calibrated containers must be used to batch ingredients



Patching

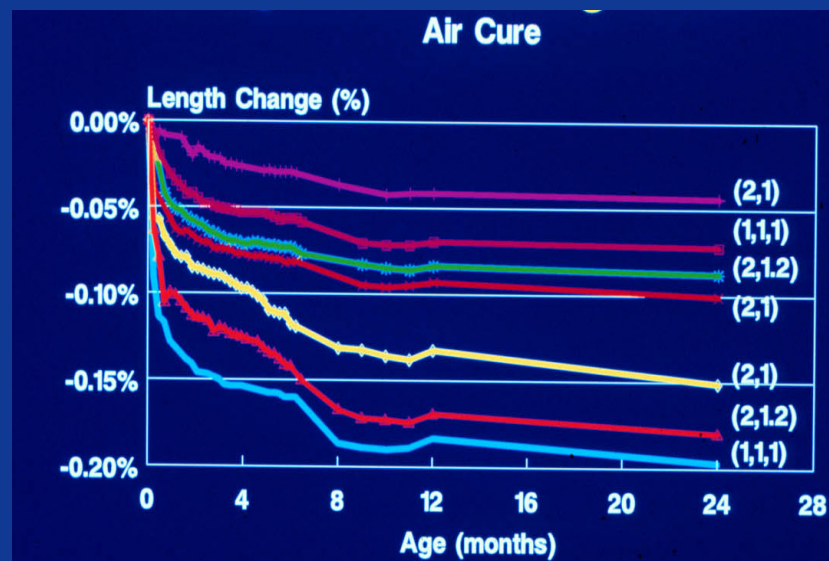
White pigmented liquid membrane curing material is applied to surface of patches.

Fewer, larger, **rectangular patches** save time and **money**: preferred to small, many sided patches.



Use patching materials with low shrinkage

Percent length change vs. age, ASTM C157



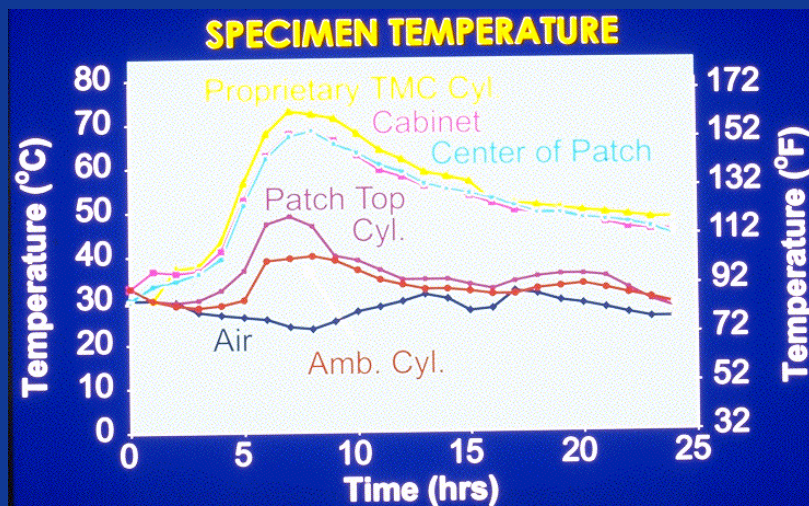
Curing time for patching materials

Hours required to obtain 2500 psi compressive strength at 4 Temperatures, F

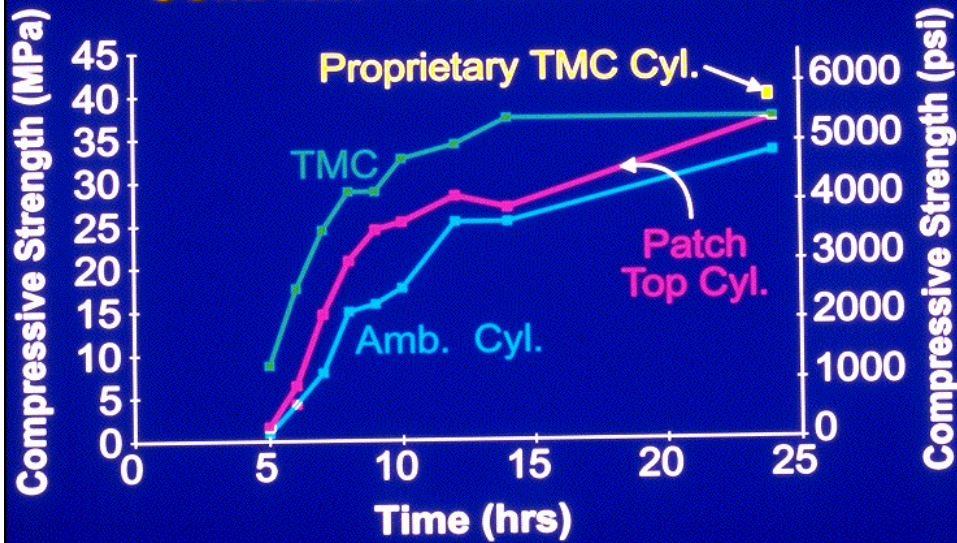
Temperature	40	55	72	90
SBC 1	5.0	1.7	1.2	0.6
SBC 2	3.6	2.2	1.5	0.6
SBC 3	6.2	3.4	2.9	2.4

Concrete temperature vs. time

Temperature matched curing of cylinders required to predict early strength of larger patches



COMPRESSIVE STRENGTH vs AGE



- Sealing concrete
- Filling cracks in concrete
- Joint repair
- Patching
- **Overlays**
- Connections for prefabricated decks

Overlays

- Multiple Layer Epoxy Overlays
- Hydraulic Cement Concrete Overlays
- Asphalt Overlay

Multiple Layer Epoxy Overlays

3 hour cure time (depends on temperature)

2 layers of epoxy and broadcasted aggregate, 0.25-in thick

(Refer to VDOT Special Provision for Epoxy Concrete Overlays)



Shot blasting surface



Placing epoxy prior to
broadcasting aggregate

Construction of Epoxy Overlays

Phase 1

- Close lane at 9 pm
- Shot blast surface
- Patch deck
- Construct/test epoxy patches
- Cure patches
- Open lane at 5 am

Phase 2

- Close lane at 9 pm
- Shot blast surface
- Place layer 1
- Place layer 2
- Cure overlay 3 hours
- Open lane at 5 am

Weekend lane closures can be more productive.

Concrete Overlay Options

Hydraulic Cement Concrete Overlays

3 to 7 day cure time (conventional repair)

- 15 % latex and type I/II cement (LMC)
- 7 % silica fume and type I/II cement (SF)
- 15 % latex and type K cement (LMC-K)
- Other HCC overlays have been used

24 hour cure time (early repair)

- 15 % latex and type III cement (LMC-HE)
- 7 % silica fume and type I/II cement (SF)

3 hour cure time (very early repair)

- 15 % latex and calcium sulfoaluminate and dicalcium silicate cement (LMC-VE)

Construction of LMC-VE Overlays

Phase 1

- Close lane at 9 pm
- Mill deck surface
- Patch deck
- Cure patches
- Open lane at 5 am

Phase 2

- Close lane at 9 pm
- Shot blast surface
- Wet surface
- Place overlay
- Cure overlay 3 hours
- Open lane at 5 am

Weekend lane closures are preferred for LMC-VE and required for silica fume and LMC-HE overlays.

Concrete removal and surface preparation

Milling rapidly removes the old surface



Shot blasting cleans and prepares the surface





Construction of LMC-VE Overlays

Placing and consolidating the overlay. Fogging to minimize cracking.

Wet burlap and polyethylene cure overlay



Typical Mixture Proportions, lb/yd³

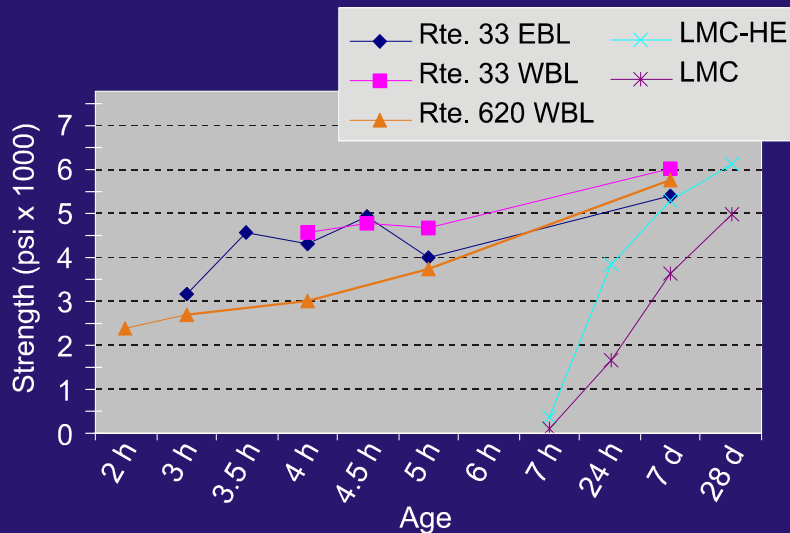
Mixture	LMC	LMC-K	LMC-HE	SF	LMC-VE
Cure Time	3 day	3 day	24 hr	24 hr	3 hr
Cement	I/II	K	III	I/II	Rapid Set
Cement	658	658	815	658	658
Silica Fume	0	0	0	46	0
Fine agg.	1571	1544	1402	1269	1600
Coarse agg.	1234	1208	1142	1516	1168
Latex (48%)	205	205	218	0	205
Water	137	137	164	282	137
Air, per cent	5	5	5	7	5

Average Compressive Strength, lb/in2

Mixture	LMC	LMC-K	LMC-HE	SF	LMC-VE
Cure Time	3 day	3 day	24 hr	24 hr	3 hr
3 hr.	-	-	-	-	3510
4 hr.	-	-	-	-	3810
5 hr.	-	-	-	-	4070
24 hr.	1810	1680	3600	2520	5440
7 day	3360	4220	4940	5310	6290
28 day	4630	5880	5700	7250	6710

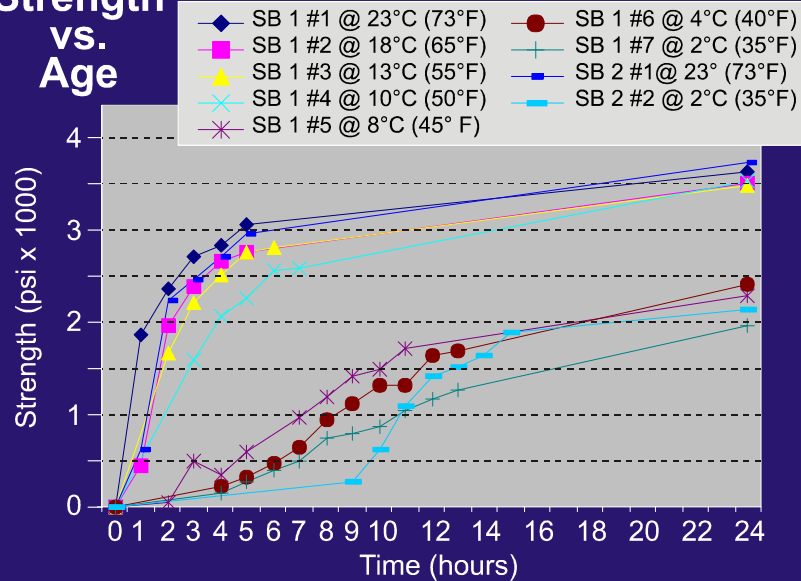
LMC Compressive Strength

Comparative Strength vs. Age



Effect of temperature on LMC-VE strength

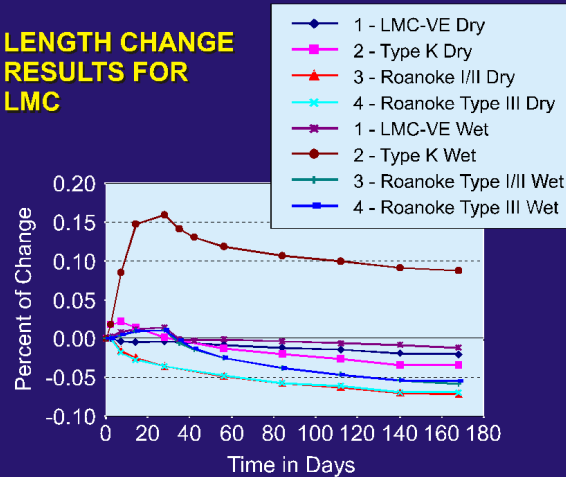
Strength
vs.
Age



Shrinkage, ASTM C157

Length change of LMC-VE and LMC-K specimens at 170 days is approximately 0.02 percent as compared to 0.06 percent for specimens of the other overlays.

LENGTH CHANGE
RESULTS FOR
LMC



Bond Strength

- After 9 years in service the tensile bond strength of VDOT's first LMC-VE overlay ranged from 176 to 301 lb/in² with all failures in the deck concrete.
- Approximately 5% of the East bound lane and 1% of the West bound lane were delaminated in the wheel paths after 9 years.
- The loss of bond in the **wheel paths** was likely caused by contamination from traffic on the milled surface prior to placing the overlay.

Cost of Rapid HCC Overlays

Mixture	LMC & SF	LMC-HE & SF	LMC-VE
Cure Time	3 day	24 hr	3 hr
Overlay	61	61	65
Misc.	23	23	23
Traffic	46	8	8
Total	130	92	96

Overlay Cost, \$/yd² (from 1994 & 1995 VDOT bids)
LMC-VE overlay placed in 2006 on I64 over Rivanna River. 5000 yd² overlay placed over 2 extended weekends saved approximately \$519,000 in user costs.



I64 Over Rivanna River, 2006



User Costs

- Road user cost calculations for I64 over Rivanna River for LMC-VE and LMC Overlay options were computed by Michael Fontaine of VTRC.
- Costs are based on the methodology described in the Texas Transportation Institute Urban Mobility Report (Schrank and Lomax, 2007, TTI).
- The report provides default values for time and vehicle occupancy.
- Assumptions include one of two lanes closed at Mile Marker 136, 16 % trucks, and maximum queue of 3.6 miles between 6 and 7 pm, 2006 dollars.



User Costs, I64 over Rivanna River

Option	LMC		LMC-VE		LMC-VE	
Lane Closure	2 Weeks		2 Long Weekends		4 Weekends	
Days, \$	Days	Cost, \$	Days	Cost, \$	Days	Cost, \$
Weekday	10	648,730	2	129,746	0	0
Saturday	2	3,854	2	3,854	4	7,708
Sunday	2	2,656	2	2,656	4	5,312
Total	14	655,240	6	136,256	8	13,020
Savings	-	0	-	518,984	-	642,220

Construction cost= \$750,000 for 5,000 yd² overlay.



Asphalt Overlay

Asphalt Overlay on Preformed Sheet Membrane
(Section 416 VDOT Road and Bridge Specifications)
Weekend placement



Sheet membrane is placed



Asphalt is paved over the sheet membrane



Asphalt Overlay

Asphalt Overlay on Liquid Membrane

Weekend placement



Liquid membrane is placed

Asphalt is paved over
the membrane

Additional information: *NCHRP Synthesis 220 Waterproofing Membranes for Concrete Bridge Decks*



Asphalt Overlay

Polymer Modified Asphalt Overlay

Low permeability asphalt overlay

No membrane

Night placement

New technology to be evaluated

Norris Bridge Overlay Replacement

Option	8 hr nights	weekends	Continuous days
Polymer Modified Asphalt	11	2	4
LMC-VE	70	7	13
A4 Concrete	not possible	not possible	17

Estimated construction time

Norris Bridge Overlay Replacement

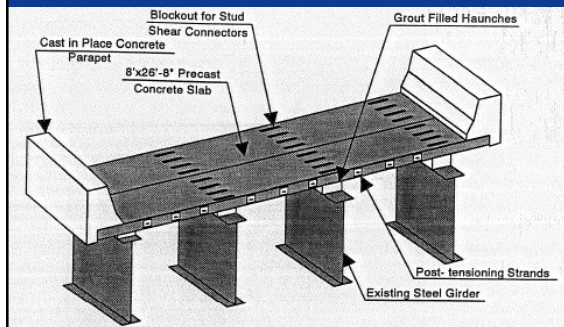
Option	8 hr nights	8 hr nights*	Week-end	Cont. days
Polymer Modified Asphalt	21	NP	104	94
LMC-VE	135	43	383	347
A4 Concrete	NP	NP	NP	454

Estimated user delay costs, \$1000s

* 300 ft lane closure (Michael Fontaine, VTRC)

Rapid hardening/curing materials

- Sealing concrete
- Filling cracks in concrete
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- Connections for prefabricated decks



(Issa et. al 1995)

Connections for prefabricated decks

- LMC-VE mortar/grout
- Magnesium phosphate mortar/grout
- Polymer mortar/grout
- Other VDOT approved patching materials with low shrinkage (refer to List 31 on VDOT website: materials/approved_lists)

Durability of Rapid Repairs

- Rapid repairs are durable when they meet the specification
- Repairs may be less durable because the contractor is rushing to complete the work during the short lane closure time
- Repairs may be less durable because of insufficient lighting and fatigue when the contractor is working at night
- Extra cleaning of the wheel paths may be needed after traffic uses the prepared surface prior to placing the overlay.

Advantages of Rapid Repairs

- User costs are less
- Traffic control costs are less
- Total costs may be less
- Repairs may be more durable
- Life cycle costs may be less
- Repairs may require fewer calendar days to complete

Disadvantages of Rapid Repairs

- Material costs are higher
- Total costs may be higher
- Repairs may be less durable
- Life cycle costs may be higher
- Repairs may require more calendar dates to complete

Conclusions

1. Successful rapid repairs include:
 - Sealing concrete
 - Filling cracks in concrete
 - Joint repair
 - Patching
 - Overlays
 - Connections for prefabricated decks
2. Use of rapid repairs can reduce user costs and increase or decrease construction costs
3. Use of rapid repairs is increasing



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Thank You

Questions?